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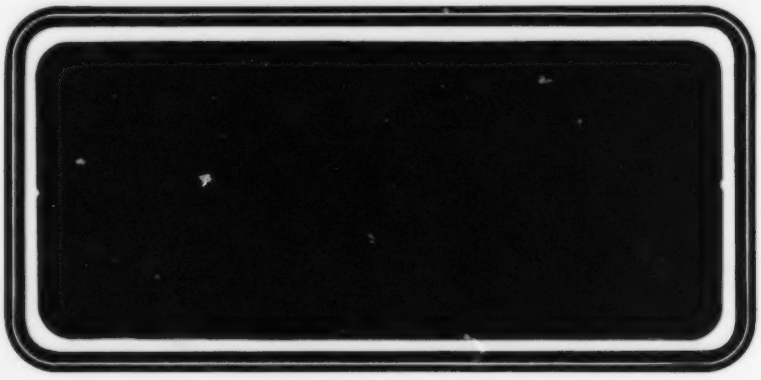
ENTENTE SUR LA MISE EN VALEUR DES RESSOURCES FORESTIERES



Canada Alberta

The Canada-Alberta Forest Resource Development Agreement is a subsidiary agreement of the Canada-Alberta Economic and Regional Development Agreement, which provides coordination and cooperation between the governments of Alberta and Canada in areas of Alberta's economic development.

The Canada-Alberta Forest Resource Development Agreement is funded equally by the governments of Canada and Alberta, from April 1, 1984, to March 31, 1989.

Its primary objectives are to ensure the long-term availability of timber supplies; to optimize timber uses; and to contribute to the growth and diversification of Alberta's economy.

The Agreement comprises three programs: Reforestation; Applied research, technology transfer and opportunity identification; and Public information, evaluation and administration. These programs are managed by a joint Directorate and are implemented by Forestry Canada and the Alberta Forest Service.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est auxiliaire à l'Entente Canada-Alberta sur le développement économique et régional, qui vise à assurer la coordination et la coopération des deux gouvernements relativement au développement économique de l'Alberta.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est financée à parts égales par les gouvernements du Canada et de l'Alberta, et a cours du 1er avril 1984 au 31 mars 1989.

Ses objectifs principaux sont assurer la disponibilité à long terme de réserves de bois; optimiser leur utilisation; et contribuer à la croissance et la diversification de l'économie de la province.

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IMPROVING WETLANDS FOR FORESTRY IN ALBERTA

by G.R. Hillman[1]

This is a joint publication of Forestry Canada and the Alberta Forest Service pursuant to the Canada-Alberta Forest Resource Development Agreement

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DISCLAIMER

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ABSTRACT

In Alberta, there is concern that the productive forest land base is decreasing as more forest land is withdrawn for nonforestry purposes. In 1985, a wetland drainage and improvement program was instituted under the Canada-Alberta Forest Resource Development Agreement (FRDA) to develop optimal silvicultural regimes for increasing growth of commercial tree species on drained wetlands, and to assess the effects of drainage on tree growth, ground vegetation, soils, peat, and local hydrology. Three experimental areas were chosen and surveyed. The first is a treed swamp, the second a treed bog, and the last a treed fen. The experimental design requires that: 1. on each area, a portion be designated for ditching and the remainder be preserved as control; 2. pretreatment data as well as posttreatment data be obtained from each site. Changes in groundwater table levels following drainage of the treed swamp are discussed.

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INTRODUCTION

In Alberta, concern about the decreasing productive forest land base as more forest land was withdrawn for other uses led foresters to consider increasing the wood-growing capability of forested wetlands. Alberta contains nearly 13 million ha of peatlands, about 11% of the peatlands in Canada (Tarnocai 1984); about 4 million of these are considered suitable for drainage and conversion to productive forests. Several drainage projects were initiated in Alberta, all but one of which are less than 5 years old (Hillman 1987). Consequently, very little information exists on the long-term effects of forest drainage in Alberta on tree growth and the environment. It is believed, however, that the potential in Alberta for increasing tree growth through peatland drainage is good (Paivanen 1980).

In 1985, in response to the concerns outlined above, the Canadian Forestry Service (CFS) and the Alberta Forest Service (AFS) prepared a research and development proposal to establish three experimental drainage areas in Alberta's boreal forest. The Wetland Drainage and Improvement Program, as it is called, is funded under category B.3 (forestry research, development, and demonstrations) of the Canada-Alberta Forest Resource Development Agreement (Anonymous 1984a). The CFS and AFS closely cooperate in all aspects of the program.

Aimed at developing cost-effective and environmentally sound technology appropriate for the boreal forest, the program's major objectives are as follows:

1. to develop optimal silvicultural regimes for increasing the growth of commercial tree species on wetlands with lowered water tables; and

2. to assess the effects of drainage on soils, local hydrology, ground vegetation, and tree growth.

The experimental design requires that portions of each study area be designated for ditching and the remainder be preserved as control. This scheme is necessary when ditching is undertaken early in a study, and meaningful amounts of pretreament data cannot be obtained. The main disadvantage of this approach is the difficulty in deciding if differences between control and treated sites are treatment effects or the result of differences in site characteristics.

The best method of evaluating drainage effects is by repeated measurements on the same site before and after drainage (Heikurainen 1964). In this method, the uncertainty due to site differences is reduced. The disadvantage, of course, is the long waiting period before treatment is implemented and results are available. Fortunately, pretreatment data for only 1 or 2 years are required to evaluate the effects of ditching on some variables, such as groundwater table levels. Because the ditch

network construction schedule for the Canada-Alberta Wetland Drainage and Improvement Program allows for the gathering of some pretreatment data, both methods outlined above are being employed in this study.

In summer 1985, a CFS-AFS team selected three forested wetlands as experimental drainage areas. The forest vegetation on each originated after a fire. The first, Goose River, is a coniferous swamp; the second, McLennan 28, is a treed bog; and the third, Wolf Creek, is a treed fen (Fig. 1). The three areas were surveyed, instrumented, and sampled in a similar manner. For this reason, and because of space and time constraints, only Goose River will be discussed in detail in the ensuing discussion.

RESEARCH PLAN FOR THE CANADA-ALBERTA AGREEMENT EXPERIMENTAL DRAINAGE AREAS

The division of each experimental area into drained and control sections is an essential feature of the research plan. The component investigations of the plan are outlined below:

1. Evaluation of the effects of drainage on tree growth

It is essential to establish and to measure tree growth permanent sample plots on both drained and control (undrained) areas. There must be a commitment to remeasure the plots periodically for at least another 20 years.

2. Adaptability of tree species

The suitability of different tree species for planting on drained wetlands needs to be assessed.

3. Groundwater table levels

Groundwater table investigations are essential to confirm if the desired water levels were attained, and to determine the relationships between tree growth and water table depth. If the drop in groundwater table level is excessive, the site may become too dry.

4. Ground temperature

Ground temperature will be affected by groundwater level control operations. It is an important factor affecting the ground freeze-thaw cycle as well as tree root growth and development.

5. Nutrient level studies and fertilization trials

Existing levels of nutrients important for tree growth, such as nitrogen (N), phosphorus (P), and potassium (K), need to be

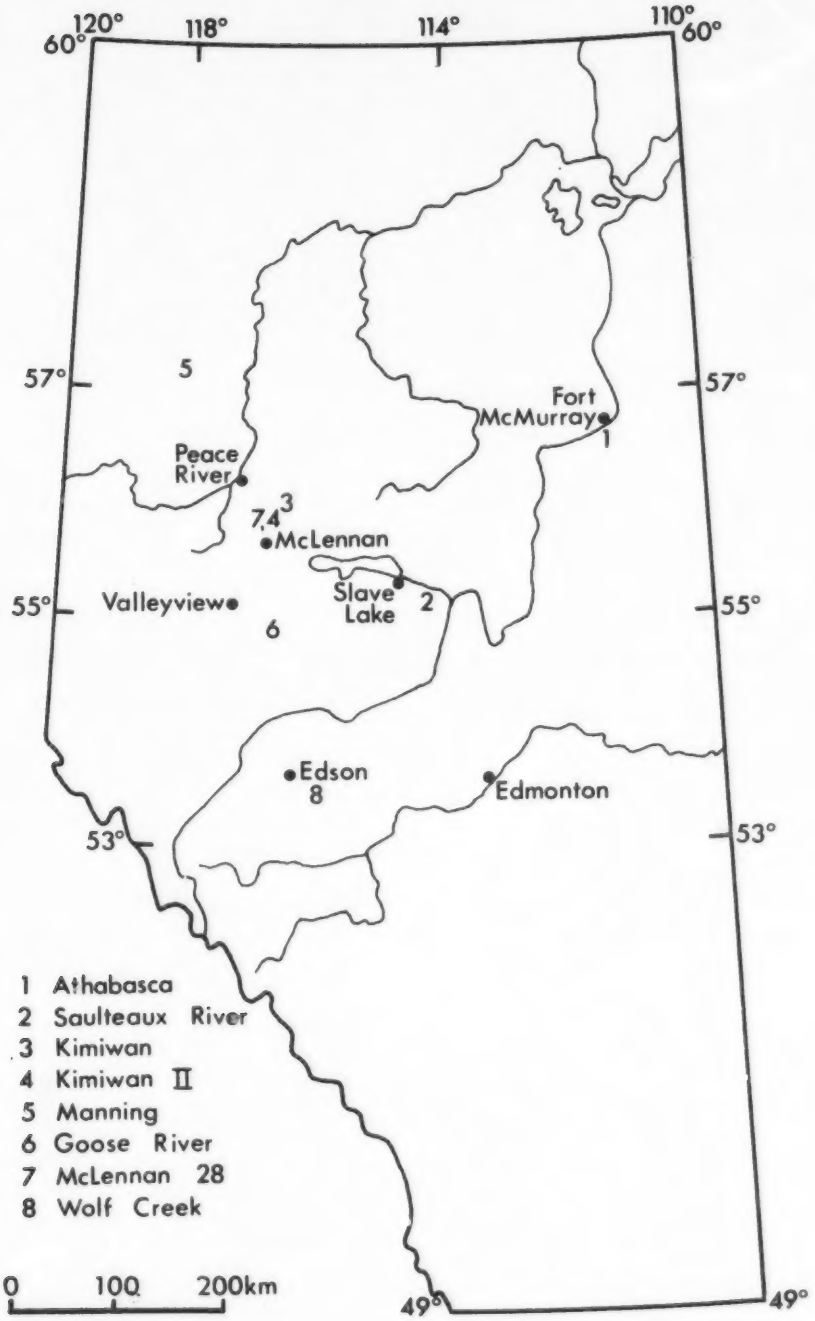

Figure 1. Locations of FRDA experimental drainage areas (6, 7, and 8) in Alberta.

determined on the experimental drainage areas. The availability of these nutrients also needs to be evaluated.

6. Ground vegetation composition

There is little or no information on the effects of drainage for forestry on ground vegetation composition in Alberta.

7. Peat subsidence

Because fibrous surface peat has a very high porosity, draining this material can result in a noticeable drop in the ground surface level. After drainage, the surface peat is no longer supported by the buoyant force of the water, and the peat volume diminishes as aeration leads to more rapid breakdown of peat material.

8. Water quality

There are three areas of water quality that need to be considered when investigating the impact of forestry drainage operations: sediment transport, changes in inorganic water chemistry, and changes in organic water chemistry.

There is scant information on the effects of forest drainage on organic chemical water quality. We do not know what components of peat have the potential to become water pollutants, nor do we know the accepted tolerable limits for such pollutants.

SITE DESCRIPTION

The Goose River experimental drainage area is located in the mixedwood boreal forest region of Alberta. It is a black spruce (Picea mariana) swamp situated about 35 km southeast of Valleyview (Fig. 1) centered on 14-68-19-W5 (54°54'N, 116°45'W; elevation 850 m). The mean annual temperature at Valleyview is 2.3°C. The average January and July temperatures are -15.9°C and 15.8°C, respectively. At the Sweathouse Tower Lookout adjacent to the site, the average July temperature is 14.7°C. The average annual precipitation for Valleyview is 519 mm, 302 mm of which falls during May through September. The average May-September precipitation for the Sweathouse Tower Lookout is 413 mm (Anonymous 1984b). The area averages 100 frost-free days annually and 2000 growing degree-days during May through September (Longley 1968).

The swamp, which covers about 320 ha, is characterized by thin (less than 1 m) peat over clay. A small creek runs westward through the site cutting through a fairly steep ravine with slopes of about 40%, near the swamp's western edge.

The swamp supports a black spruce stand 40-50 years old and a shrub understory dominated by Labrador tea (Ledum groenlandicum).

The herb stratum consists primarily of three-seeded sedge (Carex trisperma), common horsetail (Equisetum arvense), woodland horsetail (E. sylvaticum), and bog cranberry (Vaccinium vitis-idaea), with lesser amounts of cloudberry (Rubus chamaemorus). Northern reed grass (Calamagrostis inexpansa) and small bog cranberry (Oxycoccus microcarpus) are constant species but have generally lower cover. Sphagnum angustifolium and S. magellanicum are the predominant mosses in the wetter areas; S. fuscum and Pleurozium schreberi predominate in the drier areas. A few patches of reindeer lichen (Cladina mitis) occur in more open, drier, and elevated areas (Johnson 1987).

METHODS

In 1985, a weather station consisting of a recording precipitation gauge and a recording hygrothermograph was installed on the Goose River site. Survey lines were cut, topographic surveys conducted, and a topographic map produced at a scale of 1:5000 with contour intervals of 0.5 m.

Preliminary peat, water, and vegetation surveys and sampling programs were completed on a rectangular grid with 200 m sampling intervals to determine wetland, vegetation, and peat types; peat depths, nutrient status, and other site characteristics. Peat cores were taken with a Macaulay-type sampler with an inside diameter of 4 cm. Core samples (6 cm long) were taken at about 15-cm intervals for chemical analyses. The pH of the wet peat was determined immediately below the sampled segment using pH paper. Saturated hydraulic conductivity was measured in the top 1 m of soil using the piezometer method (U.S. Department of the Interior 1984). Water samples were taken at each coring site.

The core samples were oven-dried at 70°C; the moisture content (volumetric and gravimetric) and bulk density were calculated. These samples were then ashed at 480°C and the ash dissolved in 0.18N HCl. The extract was analysed for total elements (Ca, Mg, Na, K, Al, Ti, Pb, As, Cu, Fe, Mn, Zn, Ni, S, P) by an inductively coupled plasma spectrometer (ICPS). Available nitrogen, phosphorus, and potassium were determined using the phenoldisulphonic acid method (Jackson 1958, p. 197), the ammonium fluoride method (Sheldrick 1984), and the ammonium acetate extraction method (Atkinson et al. 1958, p. 29), respectively.

The water samples were acidified with HNO_3 to a final concentration of 0.6N and then analyzed by ICPS. Total nitrogen (N) for peat and water samples was determined by the modified Kjeldahl method using a technicon digestion block and Kjeltec Auto 1030 Analyzer (Tecator) (Jackson 1958, p.183).

A drainage ditch network design was prepared using field observations, a topographic map, and enlarged aerial photos.

Toth's synthetic hydraulic curve method (Toth and Gillard 1984) was used to find the optimum ditch spacings.

The drainage plan for the Goose River swamp provides for drainage of 135 ha north of the creek using mostly 40-m ditch spacings (Fig. 2). Provision was also made to evaluate different ditch spacings (30, 40, and 50 m) on a homogeneous portion of the swamp.

The ditch network was marked and 5-m rights-of-way were cleared with a D6 during winter 1985-86, when the ground was frozen. Ditch construction with a Lannen S10 excavator (Fig. 3) began in June 1986 and was completed in September 1986. About 37 km of lateral ditches (Fig. 4) and 2.73 km of main ditches were excavated, resulting in a drainage ditch density of 294 m ha^{-1}. The ditches are 0.9 m deep and about 1.4 m wide.

In summer 1986, four transects were established, one on the control site south of the creek, and three at different ditch spacings, perpendicular to ditch lines on the area to be drained. Each transect was instrumented, sampled, and surveyed to measure the effects of ditching on groundwater table levels, ground temperatures, ground vegetation composition, and peat subsidence. Peat, groundwater, and foliage samples were collected from all transects to determine the existing level of nutrients important for tree growth.

1. Permanent sample plots will be established near each transect to measure tree growth. Some plots will be established along the instrumented transects, perpendicular to the ditches so that tree growth can be related to distance from the ditch. Pretreatment growth data will be gathered through destructive sampling and stem analyses.

2. To determine which tree species adapt well to drained conditions, a 2-ha portion of the Goose River experimental area was cleared. It will be ditch-mounded in 1987 and later planted to lodgepole pine (Pinus contorta), white spruce (Picea glauca), and black spruce. Ditch-mounding is an operation in which the spoil from ditches is distributed in small piles between the ditches to serve as planting mounds for tree seedlings.

3. Groundwater table configurations were monitored through a system of groundwater wells. Between 7 and 12 5-cm diameter wells were installed on each transect in 1986. Pressure transducers connected to battery-operated data loggers were inserted in 8 of the wells to provide continuous records of changes in water levels; data were recorded at 90-minute intervals. The remaining wells were measured with a carpenter's tape. One 15-cm diameter well on the 40-m spacing, and one on the 50-m spacing was equipped with a water level recorder.

4. One temperature probe, about 3 cm in diameter, was installed on each transect. Each probe, connected to a battery-driven data

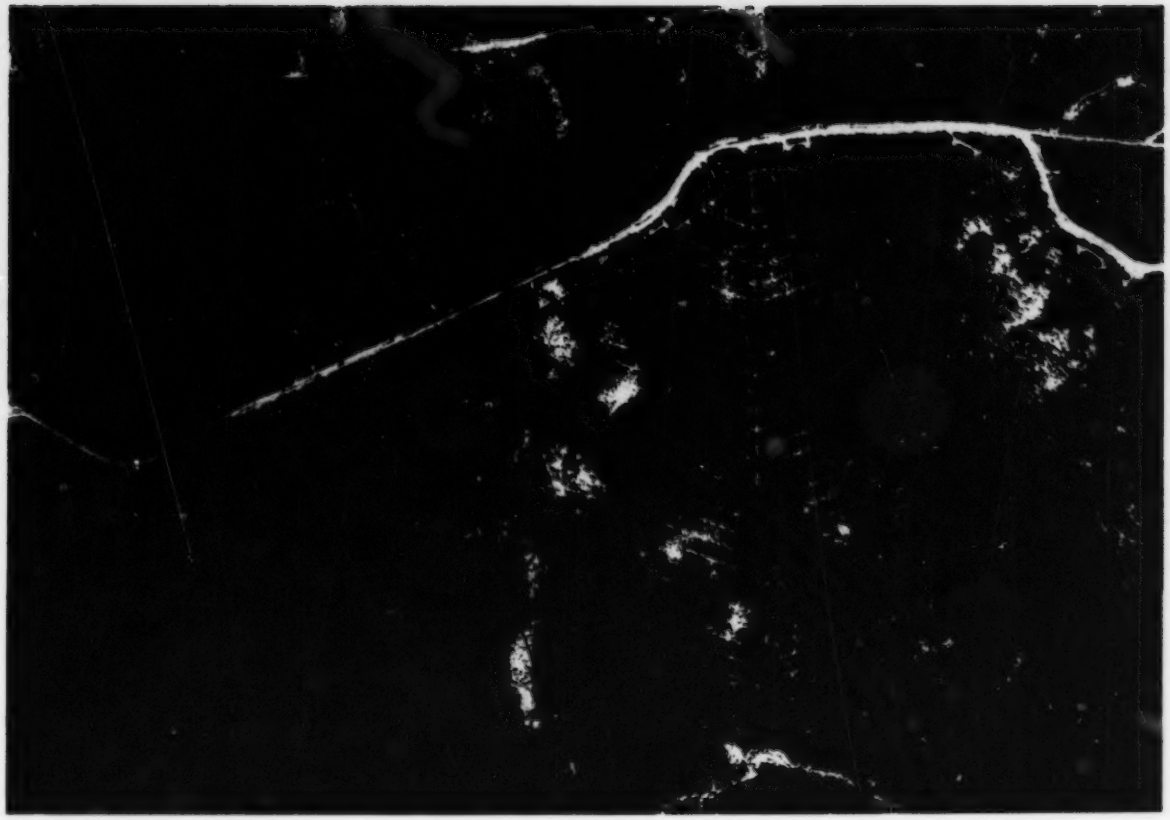

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Figure 2. Aerial photograph of ditch network on Goose River experimental drainage area.

Figure 3. Lannen S10 ditcher.

Figure 4. Lateral ditch constructed by Lannen S10 ditcher.

logger, supported sensors at the air-soil interface, and at depths of 0.075, 0.15, 0.30, 0.45, and 1.0 m. Temperature data were recorded at 90-minute intervals (3 hours in winter).

5. Peat, foliage, and groundwater samples were analyzed for the same 16 elements (including total nitrogen) tested for on the 200-m grid. The available nutrients (N, P, and K) in peat were analyzed by the methods referred to earlier.

Thinning and fertilization permanent sample plots were established on 5.8 ha in 1987. The split plot design incorporated 3 thinning treatments, 8 fertilization treatments, and 4 replicates, for a total of 96 plots. Thinning treatments consisted of no thinning, and thinning to 1600 and 2400 stems ha^{-1}. Fertilization treatments consisted of applications of N, P, NP, PK, NK, NPK, and no fertilizer.

6. Forty-eight permanent sample plots, each 1 m^2, were established near instrumented transects in 1986 to measure the effects of drainage on ground vegetation composition. Each plot will be remeasured the first year after drainage, and then every other year subsequently.

7. To measure subsidence, three 13-mm diameter steel reinforcing rods were driven into mineral soil on each transect, so that 15 cm projected above the ground surface. The projection above ground will be measured once a year after drainage.

8. Sediment loads and inorganic chemical water quality were monitored periodically at one location upstream and two locations downstream from points where water from the drainage network's main ditch enters the creek. Sediment samples were collected in glass milk bottles using a DH-48 sediment sampler. Total suspended sediment was determined using methods described in Anonymous (1971). Inorganic chemical water quality samples were collected as 'grab' samples in 250-ml plastic bottles and analyzed for total nitrogen and the 15 elements mentioned earlier. Sampling began before ditching took place.

RESULTS AND DISCUSSION

During ditch excavation it was evident that, even though the ditches were dug to a depth of 0.9 m, most of the water running into the lateral ditches came from the interface between the organic and mineral (clay) soils. At Goose River, the average depth of this boundary is 0.6 m. It would appear, therefore, that the lateral ditches could have been shallower, and dug to a depth of, say, 0.7 m. This would have resulted in a greater machine production rate and a reduction in stress on the machine because it would have excavated less clay. The lateral ditches, in particular, do not require large cross-sections to intercept and convey water to the main ditches, and would remain functional at the shallower depth. Although ditch depth does control water

table drawdown, it is believed to be less important than ditch spacing in controlling groundwater levels (Heikurainen 1964).

The Goose River site has less pretreatment data than either of the other experimental areas, but the data are sufficient to show changes in groundwater table levels resulting from drainage.

Data from the pressure transducer located 2.5 m from a ditch in the variable ditch spacing area indicated that the effect of ditching was instantaneous (Fig. 5). Between September 16 and 19, 1986 (before ditching), the water table fell at a rate of about 0.7 cm d^{-1}. On September 19, the day this particular ditch was excavated, the water table dropped sharply. Between September 19 and 25 (after ditching), it dropped 20 cm or 3.3 cm d^{-1}. During the period September 25-27, 36 mm of rain fell, causing a rise of 14 cm in the water table. In the interval between storms the water table dropped 9 cm (1.5 cm d^{-1}). A storm on October 3-4 produced 28 mm of rain and a 13-cm increase in the water table level. Thereafter, the water table level dropped at a rate of 5.5 cm d^{-1} until a small storm (6 mm) on October 6 and 7 interrupted its descent. The final portion of the hydrograph (Fig. 5) shows a drop in water level of 1.2 cm d^{-1}. On October 17, the water level was 44 cm below the ground surface, compared with 20 cm before ditching was implemented on September 19. Although the contributions from rainfall almost restored the water table to its September 16 level, the presence of the ditch prevented this level from being sustained, or from dropping at the original predrainage rate.

Water table profiles obtained from transects on the control area and on the area with variable ditch spacings (Figs. 6-9) show water table drawdown as a function of distance from the ditch. In each case, the precise level of the ground surface (the uppermost curve in each plot) was determined by differential leveling.

Measurements from two pressure transducers located in wells 32 m apart showed that the hydraulic gradient on the control (Fig. 6) approximated the topographic slope (1.5%), and that groundwater flow was directed north toward the creek. There was little difference between the average water table level for the before-drainage period and for the after-drainage period (Fig. 6).

Before drainage, a near-horizontal water table prevailed on the 40-m transect (Fig. 7A). The levels ranged in depth from 10 to 45 cm. After drainage, the profiles bent downward toward the ditches (Fig. 7B). The average profiles for the 40-m spacing (Fig. 7C) show that there was a drop in water levels of 10 cm at the center between ditches, and a 25- and 40-cm drop near the ditches.

The average groundwater table profile before ditching for the 30-m spacing (Fig. 8) lay parallel with the ground slope about 20 cm below the surface. The hydraulic gradient indicates that the groundwater flowed southward toward the creek. After ditching, the central portion of the profile was at least 15 cm lower than

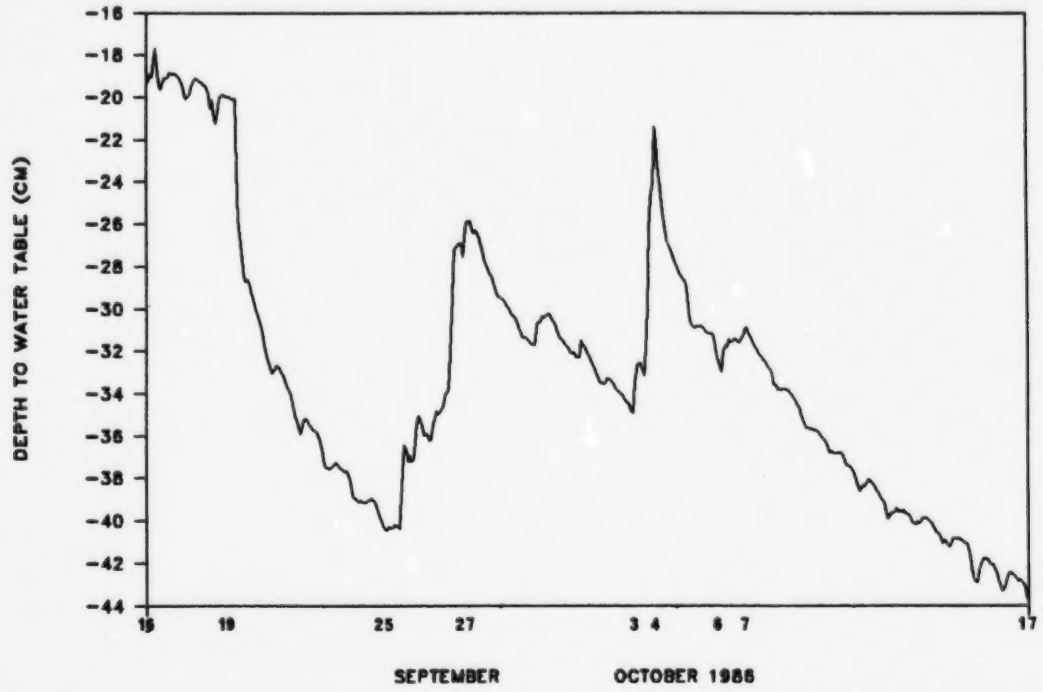

Figure 5. Groundwater table levels immediately before and after ditching, 2.5 m from the nearest ditch, Goose River site, 50-m spacing.

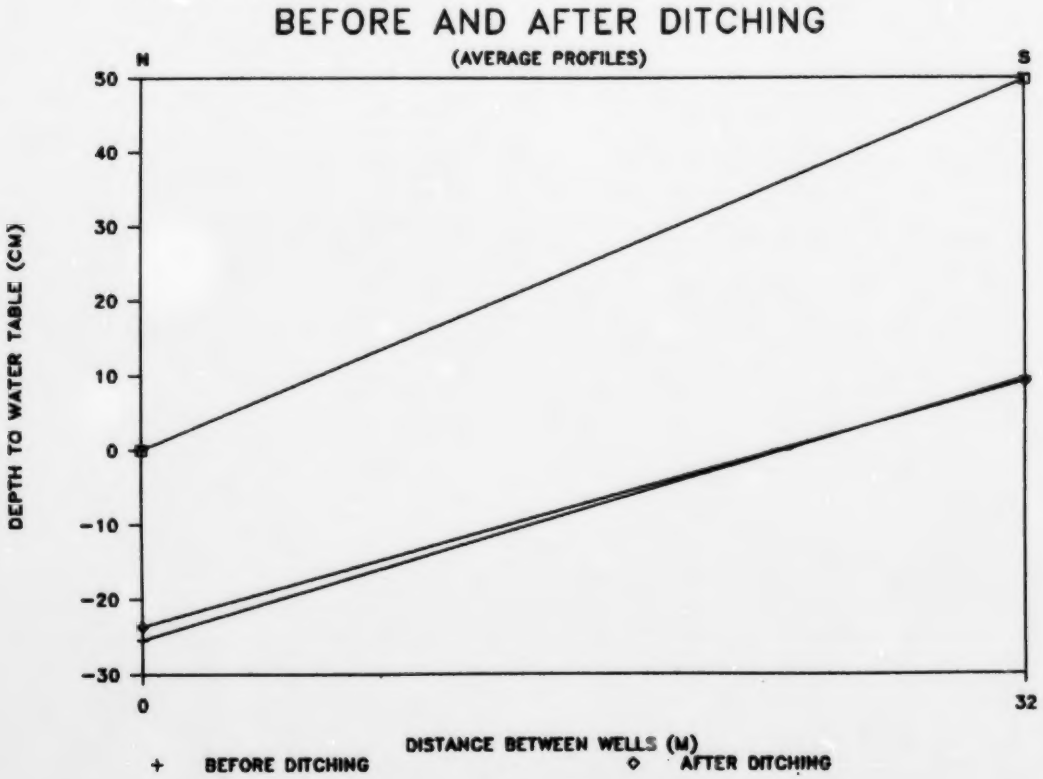

Figure 6. Goose River water table profiles, control area.

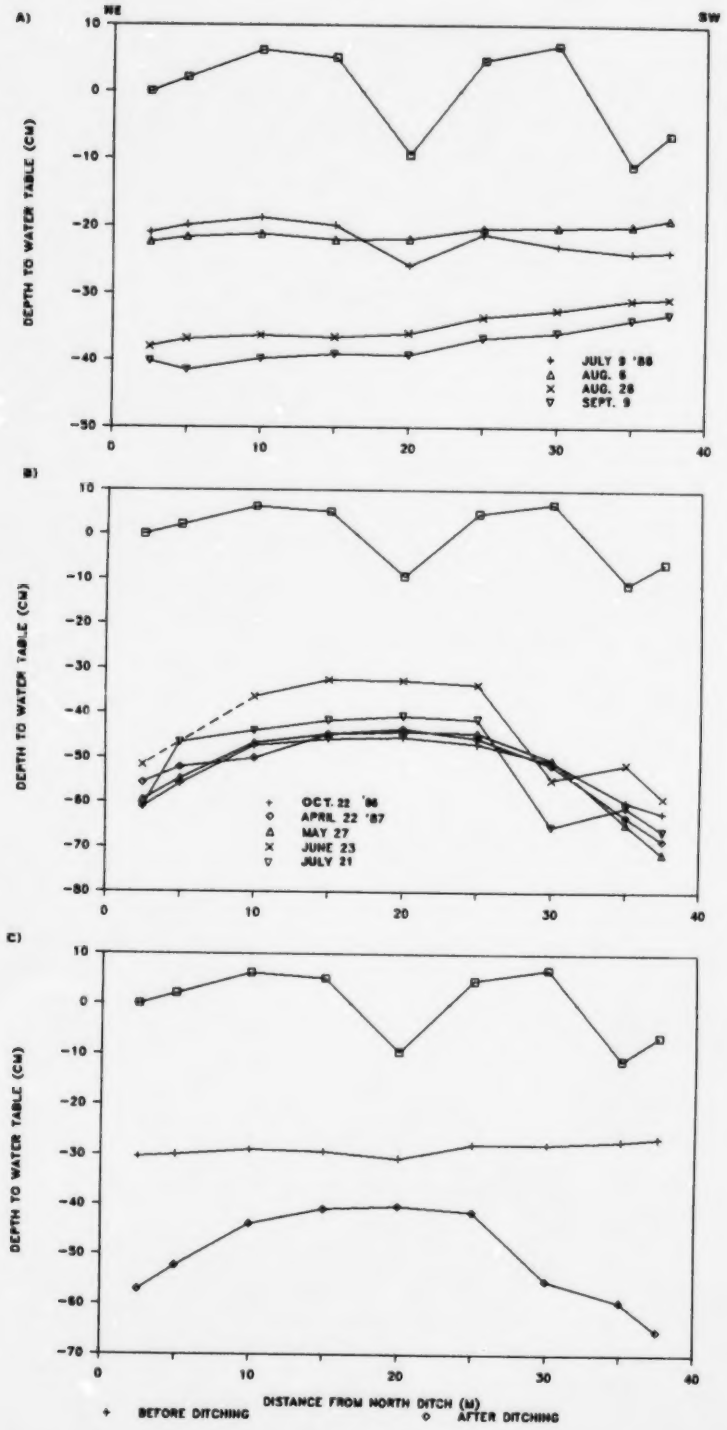

Figure 7. Goose River water table profiles, 40-m spacing; A) before ditching, B) after ditching, C) average profiles.

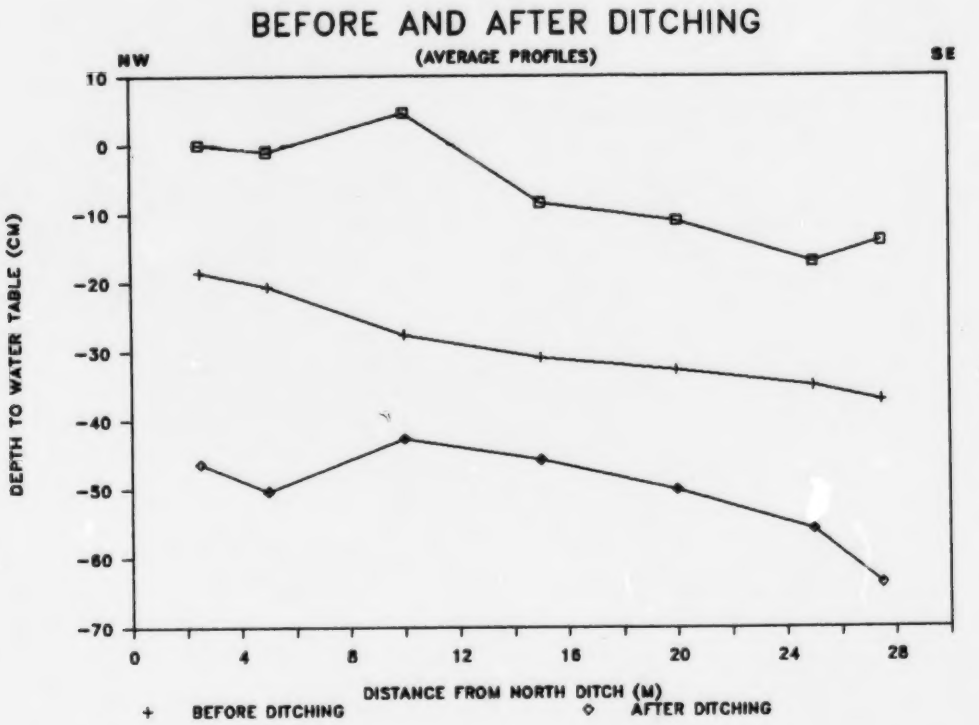

Figure 8. Goose River water table profiles, 30-m spacing.

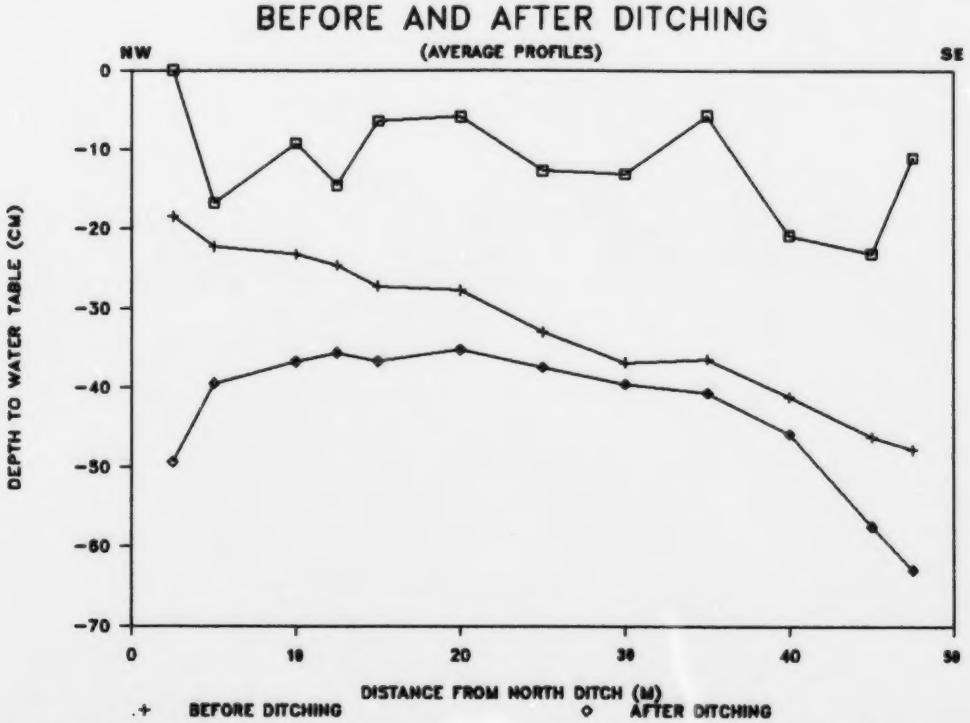

Figure 9. Goose River water table profiles, 50-m spacing.

before, while near the ditches the average water table depth had dropped by 25-30 cm to 50 cm. The 30-m spacing produced a greater drop in groundwater table levels near the center between ditches than did the 40-m spacing.

On the 50-m spacing transect, the average profiles (Fig.9) show that drainage with 50-m spacings lowered the water table less than 10 cm in the central portion of the transect. Evidently the 50-m spacing had less effect than the 40-m spacing on groundwater levels near the central portion of the transect. Near the ditches, a drop of 15 to 30 cm was achieved.

Although no statistical analyses were carried out to establish the significance of these results, it is clear from the data that drainage lowered the water table on the Goose River experimental drainage area. If the drawdown can be characterized by any one profile, it would be the "after" drainage profile in Figure 7C, because Goose River was ditched mostly with 40-m spacings. The average profiles before and after drainage indicate that, regardless of ditch spacing, ditching created a drawdown of about 30 cm 2-3 m from the ditch. Ditch spacing controlled how far the influence of the ditch would extend. Evidently, as the distance between ditches increased, the drawdown at the center between ditches decreased.

Because ditching produces a convex drawdown curve, it is important in forest drainage studies to know the relation between tree growth and depth to water table, and to identify what is meant by "optimum depth to water table" for different tree species. Trees at the center between ditches may respond differently from those located near ditches. These problems will be addressed in future studies on the Goose River site.

CONCLUSIONS

For the Goose River experimental forest drainage site, where shallow peat overlies clay, it appeared from observations of the ditching operation that the lateral ditches could have been shallower. Most of the water released by ditching issued from the interface between the organic material and the mineral soil.

Preliminary investigations of different ditch spacings (30, 40, and 50 m) on groundwater levels showed that water table profiles between ditches were roughly parabolic. Near the ditches, groundwater levels dropped about 30 cm. At the center between ditches, the water table dropped about 15 cm for the 30-m spacing, 10 cm for the 40-cm spacing, and less than 10-cm for the 50-cm spacing. Studies relating groundwater table profiles to tree growth are planned.

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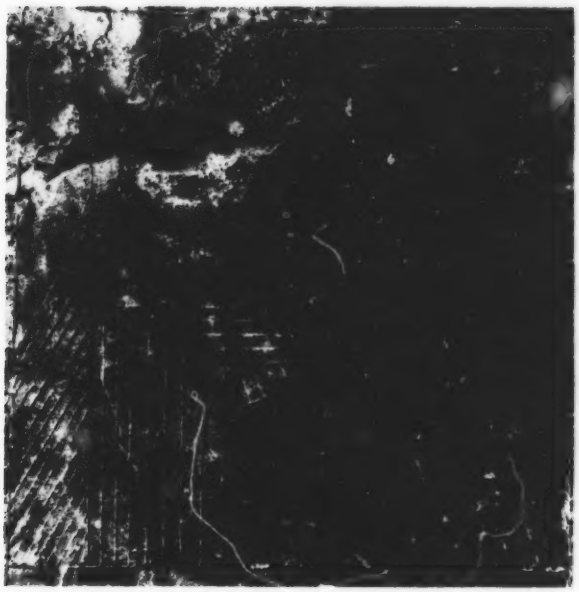
APPENDIX 1

DESCRIPTIONS OF MCLENNAN 28 AND WOLF CREEK

McLennan 28



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The McLennan 28 experimental drainage area is a treed fen, characterized by a bog cap in places, supporting young black spruce and tamarack. It is located about 15 km north of McLennan in the mixedwood boreal forest region of Alberta at an elevation of 660 m. Because the area is 6 km from the nearest road, access is difficult and requires the use of all-terrain vehicles.

The mean annual temperature at Falher, a station with long-term weather records and closest to McLennan 28, is 1.0°C. The average January and July temperatures are -17.4°C and 15.8°C, respectively. At Falher, the average annual precipitation is 423 mm, 237 mm of which falls during May through September. The average annual snowfall is 158 cm. The area averages 100 frost-free days annually and 2000 growing-degree days during May through September.

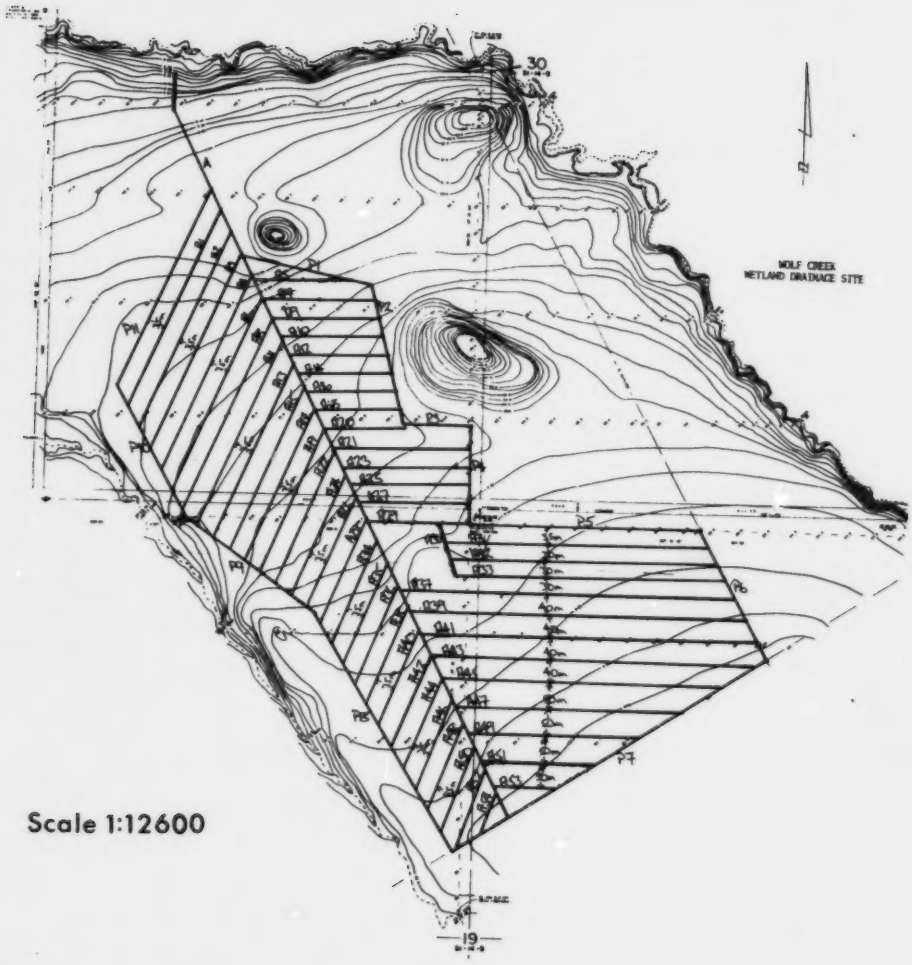
A water track located along the western edge of the site feeds into a series of beaver ponds near the northwest corner of the section. The experimental area, which slopes from the southeast toward the beaver ponds, contains only one small, well-defined stream channel.

The vegetation on the area was established after fire. The shrub stratum is dominated by various species of Salix (primarily S. farriae and S. planifolia) with lesser amounts of Betula pumila and some Ledum groenlandicum. Empetrum nigrum, a dwarf shrub, occurs sporadically. The herb stratum is dominated by Carex aquatilis, Oxycoccus spp., and Vaccinium vitis-idaea with lesser amounts of Calamagrostis inexpansa, Carex gynocrates, and C. paupercula. Rubus chamaemorus and Smilacina trifolia are constant species with low cover. The predominant mosses are Sphagnum fuscum, S. warnstorfii and Tomenthypnum nitens while Sphagnum angustifolium is present in some areas. Aulacomnium palustre is a constant moss with low cover.

An instrument network and monitoring program similar to those established on Goose River were set up on McLennan 28 in 1986. No thinning, fertilization, or ditching-mounding treatments were imposed, however.

Drainage of about 90 ha in the southern part of the section was completed in July 1987 using ditch spacings of 30, 40, 50, and 60 m. About 30 km of ditches were constructed, resulting in a drainage density of 333 m ha^{-1}. The remaining area to the north serves as a control.

Wolf Creek



The smallest (132 ha) of the three experimental drainage areas set up under the agreement is located within a confluence of Wolf Creek about 30 km southeast of Edson in the mixedwood boreal forest region of Alberta, at an elevation of 960 m.

The mean annual temperature for the area, according to weather records for Edson airport is 0.9°C. The average January and July temperatures are -15.4°C and 14.4°C, respectively. The average annual precipitation for Edson is 533 mm, 373 mm of which falls during May through September. The average annual snowfall is 205 cm. Similar averages were recorded at nearby Carrot Creek Lookout and Cold Creek Ranger Station. The area averages 80 frost-free

days annually and 1600 growing-degree days during May through September.

The Wolf Creek wetland is a treed fen characterized by peat depths ranging from 0 to more than 3 m. The shallow peat occurs near the stream channels, and the deep peat is found at the center of the confluence area away from the creeks. Peat depth increases upslope and away from the confluence area. Black spruce (80 years old) and tamarack (70 years old) are the predominant species in the fen, but mineral islands within the fen support mature lodgepole pine and white spruce.

The dominant understory shrub is Betula pumila with lesser amounts of Salix pedicellaris and Ledum groenlandicum. Andromeda polifolia is a conspicuous and constant dwarf shrub. The herb stratum is dominated by Carex aquatilis, C. chordorrhiza and Equisetum fluviatile with lesser amounts of Carex diandra and C. limosa. Galium labradoricum, Menyanthes trifoliata, Oxycoccus quadripetalus, Potentilla palustris, Smilacina trifolia, and Triglochin maritima are constant and characteristic species, but with low cover. The predominant moss species are Sphagnum warnstorfii and Tomenthypnum nitens, although Sphagnum angustifolium is prominent in certain areas; Drepanocladus vernicosus occurs in wet hollows. Alacomnium palustre and Meesia triquetra are constant species on hummocks and in hollows respectively, but with lower cover.

An instrument network and monitoring program similar to those set up on Goose River, except that no thinning, fertilization, or ditch-mounding treatments were imposed, were established on the area marked for drainage and the control area at Wolf Creek in 1986.

Two years of pretreatment data were collected from the Wolf Creek site before it was drained (60 ha) in the fall of 1987. Ditches were constructed mostly at 35 m spacings, but some were spaced 30, 40, and 50 m apart. About 20 km of ditches were excavated, producing a drainage density of 333 m ha^{-1}.

APPENDIX 2

EXPECTED BENEFITS AND MILESTONES

Expected Benefits

The Wetland Drainage and Improvement Program is expected to provide, over the long term, a measure of the change in forest growth resulting from drainage, and a set of recommendations and guidelines for operational forest drainage in the Western and Northern Region. Measurement of forest growth and depth to groundwater table are considered to be the most important components of the Program. The guidelines will cover economic feasibility, suitability of different wetland types for drainage, silvicultural prescriptions, drainage ditch network design, and environmental impact.

An assessment of the economic feasibility of operational forest drainage requires knowledge of ditching costs and incremental changes in tree growth resulting from drainage. For the FRDA experimental drainage areas, ditching costs are readily available, but tree growth data sufficient for economic analyses cannot be obtained in the short term. One alternative is to use tree growth data from trial drainage areas established earlier by the Alberta Forest Service. A good candidate area for this purpose is the trial drainage site near Fort McMurray (Athabasca Forest) which was ditched in 1975. Destructive sampling, tree ring and stem analyses will be necessary to determine pre- and post-drainage growth rates.

There are several categories of wetlands and not all of them are suitable for forest drainage. Guidelines based on The Canadian Wetland Classification System will indicate which wetland sites (bog, fen, swamp, etc) are best suited, both physically and economically, for drainage.

Silvicultural prescriptions designed to enhance forest growth include combinations of drainage with thinning and fertilization. Ditch-mounding is being tested as a method for establishing tree seedlings on wetlands. The guidelines will indicate which silvicultural treatments should be imposed, together with drainage.

Guidelines for ditch network design will be based on field experience and on simulations using mathematical models. Important elements to be considered in ditch network design include: desired average depth to water table; ditch spacing; ditch depth; number, shape, size, and location of sediment ponds; and buffer strips between the main ditches and watercourses. The desired depth to water table will be determined from studies relating groundwater table levels to tree growth and to soil water content in the unsaturated zone.

The Wetland Drainage and Improvement Program will provide information on the impact of drainage on the environment - specifically on groundwater table levels, ground temperatures, ground vegetation composition, peat subsidence, and stream water quality. Changes in ground temperatures have important implications for tree seedling establishment and tree growth. Stream water quality data provide a measure of the effectiveness of sediment ponds and buffer strips and, hence, are important for drainage network design purposes.

Milestones

1985 - Wetland Drainage and Improvement Program initiated.
- Goose River, McLennan 28, and Wolf Creek sites selected as experimental drainage areas.
- Topographic surveys completed.

1986 - Drainage ditch network designs completed.
- Transects located and most instrumentation installed.
- Ground vegetation permanent sample plots (psps) installed and measured.
- Tree growth psps established and measured on Wolf Creek.
- Ditching on Goose River completed (September 30).

1987 - Instrument installations completed.
- Black spruce stands on drained portion of Goose River thinned and fertilized. Tree growth psps (thinned and fertilized) marked and measured.
- Ditch-mounding completed at Goose River.
- Ditching completed at McLennan 28 (July 8).
- Ditching completed at Wolf Creek (November 2)

1988 - Plant ditch-mounded area at Goose River with black spruce, white spruce, and lodgepole pine seedlings.
- Complete installation and measurement of tree growth psps.
- Start tree ring and stem analyses of trees taken from Fort McMurray, Goose River, McLennan 28, and Wolf Creek to determine pre- and post-drainage growth rates.

1989 - Initiate study on groundwater, soil water, and tree growth relationships to determine best average depth to groundwater table for enhanced tree growth.

1990 - Terminate measurement of groundwater table levels, ground temperatures, and stream water quality.
- Prepare final report as required by the Canada-Alberta FRDA (to include preliminary set of recommendations and guidelines for operational forest drainage in the Western and Northern Region).

1991 - Complete preliminary evaluation of the economic feasibility of operational forest drainage in Alberta.

1992 - Develop mathematical model for drainage ditch network design purposes.

1993 - Publish complete set of recommendations and guidelines for operational forest drainage in the Western and Northern Region.

Indefinite - On the three FRDA experimental drainage areas, continue monitoring air temperature and precipitation; continue periodic measurement of tree growth and ground vegetation psps. Scientific papers will be prepared and published as the Program progresses.